Claims

1. A method for determining a position ($P_{xyz}(MT)$) of a signal transmitter (MT) comprising the steps of:

receiving a direct sequence spread spectrum signal (S_{MT}) from the transmitter (MT) in each of at least three physically separated sensors (100a, 100b, 100c, 100d) whose respective positions are known, the signal (S_{MT}) representing a set of symbols,

correlating, in each of the sensors (100a, 100b, 100c, 100d) a representation (S_{BB}, $<S_{BB}>$) of the received signal (S_{MT}) with at least one local spreading sequence (S_{PP}, S_{bin}) to determine a respective estimated transmission delay (d) of the received signal (S_{MT}), the received direct sequence spread spectrum signal (S_{MT}) having a nominal chip period (T_C), the correlating step producing a chip level synchronization at least within an uncertainty region of one half nominal chip period ($T_C/2$), and

calculating a distance (D_{MT-100}) between the signal transmitter (MT) and each of the at least three sensors (100a, 100b, 100c, 100d) based on the respective estimated transmission delays (d), **characterized by** the correlating step comprising the further sub-steps of:

over-sampling the representation (S_{BB}) of the received signal (S_{MT}) within the uncertainty region to obtain a corresponding over-sampled representation of the received signal ($<S_{BB}>$), the over-sampling being equivalent to a reduced chip period (T_{C1}) which is shorter than the nominal chip period (T_C),

selecting a local spreading sequence (S_{PP}) containing poly-phased symbol values which are different from the set of symbols represented by the received signal (S_{MT}), the selected local spreading sequence (S_{PP}) having a nominal chip period being equivalent to the reduced chip period (T_{C1}), and

cross-correlating the over-sampled representation ($<S_{BB}>$) of the received signal (S_{MT}) with the selected local spreading sequence (S_{PP}) to obtain an improved uncertainty region which is more limited than one half nominal chip period ($T_C/2$).

2. A method according to claim 1, **characterized by**, prior to said cross-correlating sub-step, the correlating step involving an auto-correlating sub-step wherein the representation (S_{BB}) of the received signal (S_{MT}) is correlated with a local copy (S_{bin}) of the transmitted spreading sequence to provide an uncertainty region of one half nominal chip period ($T_C/2$) around an auto-correlation peak (501).

3. A method according to any one of claims 1 or 2, **characterized by**:

examining a phase difference function ($\Delta\varphi$) which describes a phase difference between neighboring samples in a cross-correlation function resulting from said cross-correlating sub-step,

detecting a position (P) in said phase difference function ($\Delta\varphi$) where the phase difference between neighboring samples exceeds a predetermined magnitude ($\Delta\varphi_{Th}$), and

defining the improved uncertainty region adjacent to samples in the over-sampled representation of the received signal ($<S_{BB}>$) equivalent to said position (P).

4. A method according to any one of the preceding claims, **characterized by** the improved uncertainty region having an extension which is equal to one half reduced chip period ($T_{C1}/2$).

5. A method according to any one of the preceding claims, **characterized by** repeating said further sub-steps with progressively reduced chip periods and uncertainty regions until a desired limitation of the uncertainty region is achieved.

6. A method according to claim 5, **characterized by** the reduced chip period (T_{C1}) with respect to a first over-sampling representing an over-sampling by an integer factor of the transmitted direct sequence spread spectrum signal (S_{MT}), said integer factor being larger than one.

7. A method according to claim 6, **characterized by** the reduced chip period (T_{Cn}) with respect to any subsequent over-sampling after the first over-sampling representing an integer factor times a foregoing over-sampling, said integer factor being larger than one.

8. A method according to any one of the preceding claims, **characterized by** the over-sampling involving a linear interpolation between neighboring sampling points.

9. A method according to any one of the claims 1 - 7, **characterized by** the over-sampling involving one or more repetitions of each sampling value.

10. A computer program directly loadable into the internal memory of a computer, comprising software for controlling the steps of any of the claims 1 – 9 when said program is run on the computer.

11. A computer readable medium, having a program recorded thereon, where the program is to make a computer control the steps of any of the claims 1 – 9.

12. A sensor (100) for determining a distance (D_{MT-100}) to a signal transmitter (MT) based on a direct sequence spread spectrum signal (S_{MT}) received from the transmitter (MT), the signal (S_{MT}) representing a set of symbols, the sensor (100) comprising:

a timing unit (220) adapted to determine an estimated transmission delay (d) of the received signal (S_{MT}) based on a correlation between at least one representation (S_{BB}, $\langle S_{BB} \rangle$) of the received signal (S_{MT}) and at least one local spreading sequence (S_{PP}, S_{bin}), the received direct sequence spread spectrum signal (S_{MT}) having a nominal chip period (T_C), the timing unit (220) being adapted to produce a chip level synchronization

at least within an uncertainty region of one half nominal chip period ($T_C/2$), and

a calculating circuit (230) adapted to calculate the distance (D_{MT-100}) on the basis of the transmission delay (d) produced by said timing unit (220), **characterized in that** the timing unit (220) comprises:

a sampling circuit (221) adapted to over-sample the representation (S_{BB}) of the received signal (S_{MT}) within the uncertainty region to produce a corresponding over-sampled representation ($<S_{BB}>$) of the received signal (S_{MT}), the over-sampling being equivalent to a reduced chip period (T_{C1}) which is shorter than the nominal chip period (T_C),

at least one bank of spreading sequences (223a) adapted to provide a local spreading sequence (S_{PP}) containing polyphased symbol values which are different from the set of symbols represented by the signal (S_{MT}), said local spreading sequence (S_{PP}) having a nominal chip period which is equivalent to the reduced chip period (T_{C1}), and

a correlating circuit (222) adapted to cross-correlate the over-sampled representation ($<S_{BB}>$) of the received signal (S_{MT}) with said local spreading sequence (S_{PP}) to obtain an improved uncertainty region being more limited than one half nominal chip period ($T_C/2$).

13. A sensor (100) according to claim 12, **characterized in that** the timing unit (220) is adapted to, before cross-correlating the over-sampled representation ($<S_{BB}>$) of the received signal (S_{MT}) with said local spreading sequence (S_{PP}), auto-correlate the representation (S_{BB}) of the received signal (S_{MT}) with a local copy (S_{bin}) of the transmitted spreading sequence from the at least one bank of spreading sequences (223b) such that a chip level synchronization is obtained within an uncertainty region of one half nominal chip period ($T_C/2$) around an auto-correlation peak.

14. A sensor (100) according to any one of the claims 12 or 13, **characterized in that** it comprises a control circuit (240) adapted to control the timing unit (220) such that for a particular representation (S_{BB}, $<S_{BB}>$) of the received signal (S_{MT}) the at least one bank of spreading sequences (223a, 223b) provides an appropriate local spreading sequence (S_{PP}; S_{bin}) to the correlating circuit (222).

15. A system for determining a position ($P_{xyz}(MT)$) of a signal transmitter (MT) transmitting a direct sequence spread spectrum signal (S_{MT}), comprising

at least three physically separated sensors (100a, 100b, 100c, 100d), each sensor being adapted to receive the signal (S_{MT}) transmitted from the signal transmitter (MT), the respective position of each sensor being known, and

a central node (110) adapted to receive distance data (D_{MT-100}) from each of the sensors (100a, 100b, 100c, 100d), the distance data (D_{MT-100}) representing a respective distance between the transmitter (MT) and the sensor (100a, 100b, 100c, 100d), **characterized in that** each of the sensors (100a, 100b, 100c, 100d) is a sensor (100) according to any one of the claims 12 - 14.